

(54) Catalyst system, comprising a hydrogen cyanide using the same

(57) This invention relates to an improved catalyst system utilizing flow through radiation shielding of the reaction zone and to processes for using the catalyst

system for the production of hydrogen cyanide. The process has decreased methane usage while maintaining yield of cyanide.

<p>Catalyst system using flow-through radiation shielding and a process for producing hydrogen cyanide using the same</p>	<p>ustion, Texas 77059 (US)</p>
---	---------------------------------

(72) Inventors:
• Decourcy, Michel Stanley
Houston, Texas 77059 (US)

(71) Applicant: ROHM AND HAAS COMPANY
Philadelphia, Pennsylvania 19106-2399 (US)

(30) Priority: 15.05.1998 US 85744 P
16.03.1999 US 270410

Designated Extension States:
AL LT LV MK RO SI

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU

(22) Date of filing: 05.05.1999

(21) Application number: 99303534.4

(43) Date of publication: 24.11.1999 Bulletin 1999/47

(51) Int Cl.6: C01C 3/02, B01J 12/00

EUROPEAN PATENT APPLICATION

EP 0 959 042 A1



Europäisches Patentamt
European Patent Office
Office européen des brevets



(61)

of a platinum group metal catalyst. A decrease in oxygen yield on methane and ammonia is disclosed.

[0007] Prevention of heat loss in hydrogen cyanide production is disclosed in U.S. Patent 3,215,495 using a combination of two refractory fiber blankets having a layer of refractory particles disposed between the two blankets. The fiber blanket combination is disposed directly on the catalyst and provides a reduction in heat loss from the system resulting in decreased reactant combustion.

[0008] The present inventors have now discovered a novel catalyst system which employs flow through radiation shielding and a process for preparing hydrogen cyanide using the same wherein the following advantages are provided:

- (1) radiant-energy losses from the reaction zone are minimized thereby lowering the reactant feed portion which must be combusted to maintain the endothermic hydrogen cyanide formation reaction;
- (2) higher hydrocarbon/ammonia yields of hydrogen cyanide are realized as a direct result of the shift away from combustion of reactants;
- (3) the total volumetric load per unit of product hydrogen cyanide is reduced thus increasing production capacity more economically than other methods such as oxygen enrichment;
- (4) improved flow distribution into the reaction zone, providing more uniform catalyst temperatures which lead to higher yields;
- (5) mechanical protection of the catalyst from yield-reducing process contaminants, as with filtration;
- (6) lower upstream equipment surface temperatures, which relate pre-combustion of feed gases, helps to minimize the potential for reverse flame-front propagation and associated deflagrations, reduces equipment cooling requirements, and allows for simplified mechanical designs vs. high-temperature requirements;
- (7) reduced reaction system heat capacitance, allowing for faster heating at start-up and quicker cooling at shutdown of the reaction system (improved cycle time), faster cool-down, also relates to catalyst loss;
- (8) longer life of downstream waste heat recovery exchangers as a result of lower total heat load for the same HCN production rate;
- (9) reduced mass flow of CO_2/CO combustion products in the exit gas results in reduced bicarbonate or carbonate formation in caustic absorbers used in formation of sodium cyanide; and
- (10) less CO_2 mass flow, when absorption based ammonia recovery systems are used, such as in U.S. Patents 2,590,146; 3,104,945; 4,094,958; and 4,128,622; reduces formation of ammonium carbonate which can interfere with the stable operation.

[0001] This is a non-provisional application of prior filed May 15, 1998.

[0002] This invention relates to an improved catalyst system and to processes for using the catalyst system. In particular, to a catalyst system utilized in high temperature reactions having flow-through radiation shielding as well as to a process for preparing hydrogen cyanide using the same.

[0003] The maintenance of system energy in a high temperature catalytic reaction is important. For instance, in the manufacture of hydrogen cyanide by the ammoxidation of methane a high reaction temperature is required to maintain the highly endothermic cyanide formation reaction. In the Andrussov method for preparing hydrogen cyanide (see U.S. patent 1,934,838), ammonia, oxygen-containing gas such as air, and hydrocarbon gases such as methane are fed to a reaction system, at ambient or elevated temperature. The reactants are then reacted in the presence of a Pt-containing catalyst at temperatures of 1000 °C to 1400 °C to produce hydrogen cyanide.

[0004] In such high temperature catalytic reactions, a considerable amount of system energy may be lost as radiant energy. One mechanism for loss of radiant energy, in high temperature catalytic reactions, occurs when a metal containing catalyst material is utilized in the reaction. Such a catalyst material will glow as a result of the high temperatures of the reaction. Consequently, energy in the form of radiant energy is emitted from the glowing catalyst. Such radiant energy is lost to uncaptured heating of upstream equipment, refractory, cooling jackets and the surrounding environment.

[0005] In the aforementioned Andrussov process for preparing hydrogen cyanide, the system energy demand is primarily met through combustion of a portion of the hydrocarbon/ammonia reactant feed gases. Accordingly, the net result of such loss of radiant energy is an increase in consumption of hydrocarbon/ammonia for combustion to maintain the system energy. Consequently, either additional hydrocarbon/ammonia feed gas is utilized or the yield of hydrogen cyanide product decreases because less reactants are available to the reaction because of combustion. As a result, there is an increase in manufacturing costs because an increased proportion of reactants are used to fulfill the reaction system's energy demands. Accordingly, there is a constant demand for means to decrease reactant combustion thereby improving hydrogen cyanide yield.

[0006] Pre-heating of reactant gases has been disclosed as a means of decreasing reactant combustion and improving hydrogen cyanide yield. In U.S. Patent 3,104,945 a process for preparing hydrogen cyanide is disclosed where air methane and ammonia are pre-heated and mixed before being reacted in the presence

221] In one embodiment of the catalyst system, the catalyst 5 and flow through catalyst support 7 are combined into a singular platinum containing metallic catalyst "pack". In a preferred embodiment, the flow through radiation shield 3 and the catalyst 5 are combined into a single ceramic foam component, with the downstream portion composed of a platinum containing, catalytically active material. In a more preferred embodiment, the catalyst 5 and the catalyst support layer 7 are combined into a single ceramic foam component, with the upstream portion composed of a platinum containing, catalytically active material. In a most preferred embodiment, the catalyst 5, the flow through radiation shield 3, the catalyst 5, and the catalyst support layer 7 are combined into a singular reaction zone. Additionally, the catalyst 5 and the catalyst support layer 7 are combined into a singular reaction zone.

While the present invention is described in the drawings and in the foregoing description, it is to be understood that the invention is not limited to the specific details shown and described. For instance, upflow reactors such as the reactor disclosed in WO 97/09273 may also benefit from the use of the catalyst system of the present invention. Specifically, by placing the shield downstream of the mixing zone, and upstream of the catalyst lower pre-heating zone, temperatures are required therefore minimizing detonation and other flammability hazards. The subject application relies on higher mixed stream velocity to prevent hazards. The catalyst system of the present invention provides flexibility in velocity rates by contributing to a reduction by allowing lower mixed stream temperatures. Additionally, the catalyst system helps dis-

The process and catalyst system of the reaction will be described using the attached figure 1 describes a first embodiment of the invention. As indicated in Figure 1, the catalyst reaction is contained within a reactor 2. The system includes a flow through radiation shielded upstream of a reaction zone 4, a catalyst 5 disposed downstream of the catalyst 5, and temperature sensing devices 6 disposed between the catalyst and the catalyst support 7 in the reaction zone. It is to be understood that in other embodiments the catalyst sensing device(s) 6 may be disposed in the radiation shield 3 or after the catalyst support 1 and Figure 4, i.e., the proximity, between the components is expanded within the reactor for

throughout this specification and claims the "through" is defined as the ability of a substance as a reactant, to pass not only around individual pieces, but also to move through individual pieces of the porosity or high internal surface area.

Understood that ranges of 1-15 or 5-20 are also

[0009] In one aspect of the present invention, there is provided a process for preparing hydrogen cyanide, including the steps of: (A) feeding reactants including at least one hydrocarbon, at least one nitrogen containing gas and at least one oxygen containing gas into a reactor; (B) pre-heating the reactants by passing the reactants through an at least partially heated radiation shield comprising one or more pieces of a flowthrough ceramic material, into a reaction zone, the radiation shield having been at least partially heated by absorbing at least a portion of radiant energy produced in the reaction zone; (C) reacting the reactants at a temperature of 800° C. to 1400° C. in the presence of a platinum group metal catalyst disposed within the reaction zone to produce hydrogen cyanide; (D) monitoring the temperature of the reaction zone; and (E) adjusting the oxygen content of the reactants to maintain the reaction temperature within a range of 800° C. to 1400° C.

[0010] In a second aspect of the present invention, there is provided a catalyst system for use in a high temperature chemical process, including: (A) a reaction zone having a catalyst disposed therein; (B) a radiation shield including one or more pieces of a flowthrough ceramic material disposed upstream of the reaction zone for (i) absorbing at least a portion of radiant energy produced in the reaction zone, and (ii) transferring heat formed from absorbing the radiant energy to reactants flowing therethrough into the reaction zone; and (C) one or more temperature sensing devices disposed within the reaction zone.

[0011] Figure 1 depicts a partial view of a reactor containing one embodiment of a catalyst system of the present invention.

[0012] Figure 2 depicts top and side views of another embodiment of a catalyst system of the present invention.

[0013] Figure 3 depicts top and side views of another embodiment of the present invention of a radiation shield having one or more ceramic tiles having beveled edges.

[0014] Figure 4 depicts a partial view of a reactor having one embodiment of the present invention.

[0015] Figure 5 depicts a restraining device utilized in one embodiment of the present invention.

[0016] Throughout this specification and claims, unless otherwise indicated, references to percentages are by weight and all temperatures by degrees centigrade. It is also to be understood that for purposes of this specification and claims that the range and ratio limits, recited herein are combinable. For example, if ranges of 1-20 and 5-15 are recited for a particular parameter, it is recited that the range and ratio limits are combinable.

[0017] This specification and claims that the range and ratio limits, recited herein are combinable. For example, if ranges of 1-20 and 5-15 are recited for a particular parameter, it is recited that the range and ratio limits are combinable.

tion of ammonia purification/distillation columns and is also highly corrosive to carbon steel thereby forming ferrous/ferriic compounds in the recycle ammonia stream which are damaging ammonia compression equipment and may also poison the catalyst.

5 the middle portion, and the catalyst support layer 7 the downstream portion.

[0022] Generally, reactants 1 are fed into the reactor 2 at inlet 10. The reactants 1 are then passed through radiation shield 3 being the upstream component, the catalyst

downstream portion.

2 at inlet 10. The reactants 1 are then passed through radiation shield 3 is at least partially emanating from the heated reaction zone 4. As reactants 1 are heated by the heated radiation shield 3, the pre-heated reactants 1 pass into the reaction zone 4 wherein they are contacted with the catalyst 5 to form hydrogen cyanide or alternatively are combusted in the reaction zone 4 to maintain system energy. The product gases 11 pass out of the reaction zone through the support layer 7 downstream for cooling and separation of hydrogen cyanide product.

[0023] The catalyst system may also include a restraining device 12 for securing the radiation shield 3 which allows individual shield pieces, such as ceramic foam tiles, or the radiation shield to pivot upstream. During any shutdown of the system wherein feed gases are ceased to be fed to the reactor a pressure differential may occur which can cause the tiles to be lifted or displaced upstream or even damaged. One embodiment for the restraining device 12 is illustrated in Figure 2. The restraining device 12 is placed above the one or more tiles of the radiation shield 3 and is attached to a castable refractory 13 at the wall by mounting hardware 14 so that a gap is created between the radiation shield 3 and the restraining device 12. Accordingly, in the instance wherein individual tiles of the shield 3 are lifted or displaced upstream, the tiles will pivot upstream and contact the restraining device 12 thus opening a gap to allow the pressure to equalize. Once the pressure differential is relieved the tile(s) will fall back into the correct position by the force of gravity. It will be recognized by those skilled in the art that the dimension of the gap will depend on the size of the tiles and be set to a distance which is suitable to allow the tile(s) to pivot and return to the correct position. It will be recognized that although not required the benefits of the restraining device will be beneficial in any embodiment of the present invention and will be especially beneficial when two or more ceramic material tiles are utilized as the radiation shield 3. Any restraining device, suitable for use in a high temperature chemical reactor and of a composition, e.g., iron, which does not cause catalyst contamination and poisoning, in a preferred embodiment, the restraining device 12 is a 300 series stainless steel restraining screen as depicted in Figure 5.

[0024] As recited above, the process for preparing hydrogen cyanide includes feeding reactants 1 into a reactor 2. The reactants include at least one hydrocarbon, at least one nitrogen containing gas, and at least one oxygen containing gas may be the same as the nitrogen

[0025] The at least one hydrocarbon may be an aliphatic or substituted aliphatic, cycloaliphatic or substituted cycloaliphatic, or aromatic or substituted aromatic hydrocarbon or a mixture thereof. Suitable examples include, without limitation, methane (CH_4), ethylene (C_2H_4), ethane (C_2H_6), propylene (C_3H_6), propane (C_3H_8), butane (C_4H_{10}), methyl formate, in a preferred embodiment, the at least one hydrocarbon is methane or a mixture of one or more hydrocarbons containing methane. The at least one nitrogen containing gas includes, without limitation, ammonia or formamide. In a preferred embodiment, the at least one nitrogen containing gas is ammonia or mixtures of ammonia with one or more nitrogen containing gases. The at least one oxygen containing gas may be any material containing an amount of oxygen suitable to maintaining combustion to provide heat for endothermic hydrogen cyanide formation. Suitable examples include, without limitation, air, oxygen-enriched air, pure oxygen gas, carbon monoxide (CO), carbon dioxide (CO_2), or mixtures thereof or oxygen containing compounds which upon decomposition would provide oxygen. Suitable examples include peroxides, ketones, ethers, and the like.

[0026] The feed gases may be filtered and/or preheated prior to being flowed through the radiation shield into the reaction zone. Generally, the feed gases, with or without preheating, are mixed and then supplied to the reactor at a temperature from ambient temperature up to the reaction temperature. When preheating and/or oxygen enrichment is used and as the preheating temperature and/or oxygen concentration increases, the occurrence of flashback and/or detonation is more likely. Use of the catalyst system of the present invention allows use of lower preheating temperatures and/or modified oxygen content because the feed gases are pre-heated by the radiation shield 3.

[0027] When fed into the reactor 2 the reactants 1 are partially heated by passing the reactants 1 through an reaction zone 4. The amount of preheating will depend on whether the feed gases were preheated prior to being fed to the reactor 2. The radiation shield 3 is characterized by an ability to readily absorb radiant energy lost from the reaction zone, to allow feed gases to pass through, and to conduct the absorbed energy from itself into the feed gases such that they are effectively pre-heated as they pass through the shield. While the typical application of insulating materials is to retard energy loss due to the mechanisms of conduction and convection, the majority of the (previously unrecovered) energy losses in the hydrocarbon cyanide system are due to the mechanism of thermal radiation. In the prior art, without the radiation shield, radiant energy would leave the reaction zone and would be lost to unproductive heating of upstream equipment, refractory, cooling jackets, and the surrounding environment. Through the absorption-and-

thermal devices (RTD's) or infra-red temperature monitoring devices. Preferred temperature sensing or temperature and chemical protection from the high reaction temperature devices are available, for instance, from Gayesco, Inc. of Pasadena, Texas. [0042] Finally, in response to the temperature measurement, the ratio of oxygen to reactants is adjusted to maintain the temperature at a range of 800°C to 1400°C, preferably 900°C to 1350°C, more preferably 1000°C to 1300°C. That is, since the amount of oxygen present in the reaction zone 4 limits the amount of reactant combustion, the temperature in the reaction zone 4 can be controlled by adjusting the oxygen level. Furthermore, temperature can also be controlled by preheating of the reactants with or without oxygen adjustment. [0043] The process of making hydrogen cyanide of the present invention may further include the step of measuring the composition of the product gases, reaction zone and the composition of the feed gases. Such composition measurement allows adjustment of feed composition, e.g., the NH_3 to CH_4 reactant ratio, to maximize yield. Suitable real-time measuring devices are known in the art and include, without limitation, gas chromatography, mass spectrometry, gas chromatography-mass spectrometry, Fourier transform infrared analysis (FTIR) and the like as well as other on-line analytical techniques. In an alternative embodiment, composition analysis may be done by sampling with subsequent wet laboratory methods and instrumental laboratory methods known in the art. Alternatively, given suitable composition versus temperature data it is believed that a suitable model may be constructed whereby temperature could be inferred from the on-line composition measurements described above. [0044] The process may be carried out at any pressure, that is at atmospheric, sub-atmospheric, or super-atmospheric pressure. When practicing the process for preparing hydrogen cyanide of the present invention, reaction conditions, reactors, etc., known in the art are utilized and are not described in detail herein. [0045] Although the process for preparing hydrogen cyanide and the catalyst system used therein has been described in terms of the Andrusow reaction for preparing hydrogen cyanide, it is also contemplated that the catalyst system of the present invention may be used in other high temperature chemical processes. For instance, the catalyst system may also be beneficially employed to control radiant energy losses in the flame zone of combustion-based equipment such as heaters, direct-fired boilers, flares, furnaces, and thermal oxidizers, thereby providing a fuel savings. In these applications, the captured energy would be used to provide preheating of entering combustion air or fuels being delivered to the flame front. Additional applications include elec-

which leads to enhanced residence time and better mass transfer thereby improving reaction yields. Also, such gauzes have greater durability over repeated thermal cycles. [0036] Furthermore, a platinum group metal granular catalyst may be utilized alone or in combination with a catalyst gauze. Such a granular catalyst may be in the form of pellets, spheres, chips, turnings, or in the form of a platinum group metal coating on an inert particle substrate such as beryl, alumina, sillimanite and the like. Suitable catalysts are described in, for instance, U.S. Patent 5,356,603, and are available from Johnson-Matthey, Inc. of Valley Forge, Pennsylvania; PGP Industries, Inc. of Santa Fe Springs, California; Engelhard, Inc. of Iselin, New Jersey. [0037] As recited above, the catalyst is a platinum group metal catalyst. Accordingly, the platinum group metal catalysts is prepared from platinum, rhodium, iridium, palladium, osmium, or ruthenium or a mixture or alloy of two or more metals thereof. Alternatively, the catalyst may be a mixture of a platinum group catalyst as described above and at least one other material including, but not limited to, cerium, cobalt, manganese, magnesium, and ceramic materials. Generally, the catalyst is an alloy of two or more platinum group metals containing 50 up to 100, preferably 75 up to 100, more preferably 85 up to 100 percent platinum. The preferred alloy is a platinum-rhodium alloy having 50 up to 100, preferably 75 up to 100, more preferably 85 up to 100 percent platinum, and 0.001 up to 50, preferably 0.1 up to 25, more preferably 1 up to 15 percent rhodium. [0038] The catalyst is generally supported on at least one flow through catalyst support 7 which may include one or more layers of material such as metallic support screen(s), pre-cast ceramic or refractory, cast-in-place refractory, ceramic foam, ceramic packing, or any one of the flow-through materials described as being useful for the radiation shield. [0039] Generally, the reactants are reacted at a temperature of 800°C to 1400°C, preferably 900°C to 1350°C, more preferably 1000°C to 1300°C. [0040] Once the reaction has been initiated and the reaction temperature achieved, monitoring of the temperature of the reaction zone 4 is performed. Use of the catalyst system having a radiation shield as described herein results in a process for preparing hydrogen cyanide which is much more sensitive to changes in feed composition than a process using prior art catalyst systems. Accordingly, without continuous monitoring of reaction zone temperature severe, irreversible catalyst damage may result. As a result reliable temperature measurement is required to maintain the reaction temperature at appropriate values. [0041] Generally, the temperature sensing or monitoring device 6 is any known device which is configured to survive the high temperatures and chemical compositions existing within the reaction zone. Suitable devices include, without limitation, thermocouples, resistive

isolated from the product gases. The feed ratio for the 1000 hour run of methane to ammonia was found to be 0.88:1.00 to 0.85:1.00 at an average hourly hydrogen cyanide yield of 64.08% and at a constant temperature of 1150°C.

[0049] A comparison of Example 1, which employs a process for preparing hydrogen cyanide which uses a conventional reactor having a catalyst system wherein the catalyst is not shielded, versus Example 2, which employs the process for preparing hydrogen cyanide of the present invention which uses a reactor having a catalyst system having flow through radiation shielding according to the present invention, shows a 10 to 12 percent reduction in methane usage. This reduction in methane usage is achieved without sacrificing hydrogen cyanide yield which is constant (approximately 63 to 64 % in both examples). Such savings in methane usage is attributable to the catalyst system of the present invention which has a radiation shield which absorbs radiant energy produced in the reaction zone and transfers the energy in the form of heat to reactants passing there through, thus pre-heating the reactants. Consequently, radiant energy previously unrecovered in the prior art is recovered and utilized to reduce reactant combustion thus lowering the manufacturing cost of the process. Furthermore, as a result of the methane usage being lower, the mass flow through the system is lower. Consequently, since the amount of CO/CO_2 is unchanged, the mass flow of CO/CO_2 is lower in the exit gas, therefore leading to reduced bicarbonate, carbonate and carbamate production and the problems described above which are associated therewith.

[0046] The following Examples are provided as an illustration of the present invention.

Example 1

[0047] Ammonia, methane and air reactants in an initial mixing ratio of 1:0.9:9 were fed to a conventional reactor without a radiation shield as depicted in Figure 4. Ammonia was fed at an initial rate of 4500 pounds/hour with the other reactants fed at initial rates which maintain the initial mixing ratio. The reactants were introduced into a reaction zone having a platinum-rhodium (90:10) corrugated gauze catalyst purchased from Johnson-Matthey, Inc. of West Chester, Pa., and a hydrogen cyanide formation reaction was carried out at an initial temperature of 1150°C for 850 hours. The feed ratios were adjusted during the run to maintain a constant yield of hydrogen cyanide. The product gases containing hydrogen cyanide was isolated from the product gases. The feed ratio of methane to ammonia for the 850 hour run was found to be in the range from 1.00:1.00 to 0.95:1.00 at an average hourly yield of hydrogen cyanide of 63.23% and at a constant target temperature of 1150°C.

[0048] Ammonia, methane and air reactants in an initial mixing ratio of 1:0.9:9 were fed to a reactor embodying the catalyst system of the present invention as depicted in Figure 1. Ammonia was fed at an initial rate of 4500 pounds/hour with the other reactants were fed at initial rates which maintain the initial mixing ratio. The reactants were introduced into a reaction zone as depicted in Figures 1 and 2 having a platinum-rhodium (90:10) corrugated gauze catalyst purchased from Johnson-Matthey, Inc. of West Chester, Pa., a radiation shield of alumina foam tiles fitted together having 20 pores per inch with beveled edges purchased from Porvair Advanced Materials, Inc. of Hendersonville, North Carolina and high temperature and chemical resistant thermocouples purchased from Gayesco Company of Pasadena, Texas. A hydrogen cyanide formation reaction was carried out at a target temperature of 1150°C for 1000 hours. The methane/ammonia feed ratios were adjusted during the run to maintain a constant yield of hydrogen cyanide and the air feed was adjusted according to the temperature measurement to provide a suitable amount of oxygen to maintain the temperature at the target 1150°C. The product gases containing hydrogen cyanide were cooled to 300°C and hydrogen cyanide

Claims

1. A process for preparing hydrogen cyanide, comprising the steps of:

- (A) feeding reactants comprising at least one hydrocarbon, at least one nitrogen containing gas and at least one oxygen containing gas into a reactor;
- (B) pre-heating the reactants by passing the reactants through an at least partially heated radiation shield, comprising one or more pieces of a flowthrough ceramic material, into a reaction zone, the radiation shield having been at least partially heated by absorbing at least a portion of radiant energy produced in the reaction zone;
- (C) reacting the reactants at a temperature of 800°C to 1400°C in the presence of a platinum group metal catalyst disposed within the reaction zone to produce hydrogen cyanide;
- (D) monitoring the temperature of the reaction zone; and
- (E) adjusting the oxygen content of the reaction zone;

55

50

45

40

30

25

20

15

10

5

11. The catalyst system of claim 6, wherein the catalyst is a platinum group catalyst selected from platinum, rhodium, iridium, palladium, osmium, ruthenium, mixtures or alloys thereof.
12. The catalyst system of claim 4, further comprising a restraining device for securing the radiation shield which allows individual ceramic material pieces of the radiation shield to pivot upstream without displacement or damage.

2. The process of claim 1, further comprising adjusting the NH_3 to CH_4 reactant ratio to maximize product yield.
3. The process of claim 1, wherein the one or more pieces of flowthrough ceramic material are one or more ceramic foam tiles having from 5 to 1000 pores per inch.

4. The process of claim 3, wherein the one or more pieces of ceramic foam tiles are fitted to one another at least on one side.
5. The process of claim 3, wherein the one or more ceramic foam tiles have a beveled edge on at least one side.
6. A catalyst system for use in a high temperature chemical process, comprising:

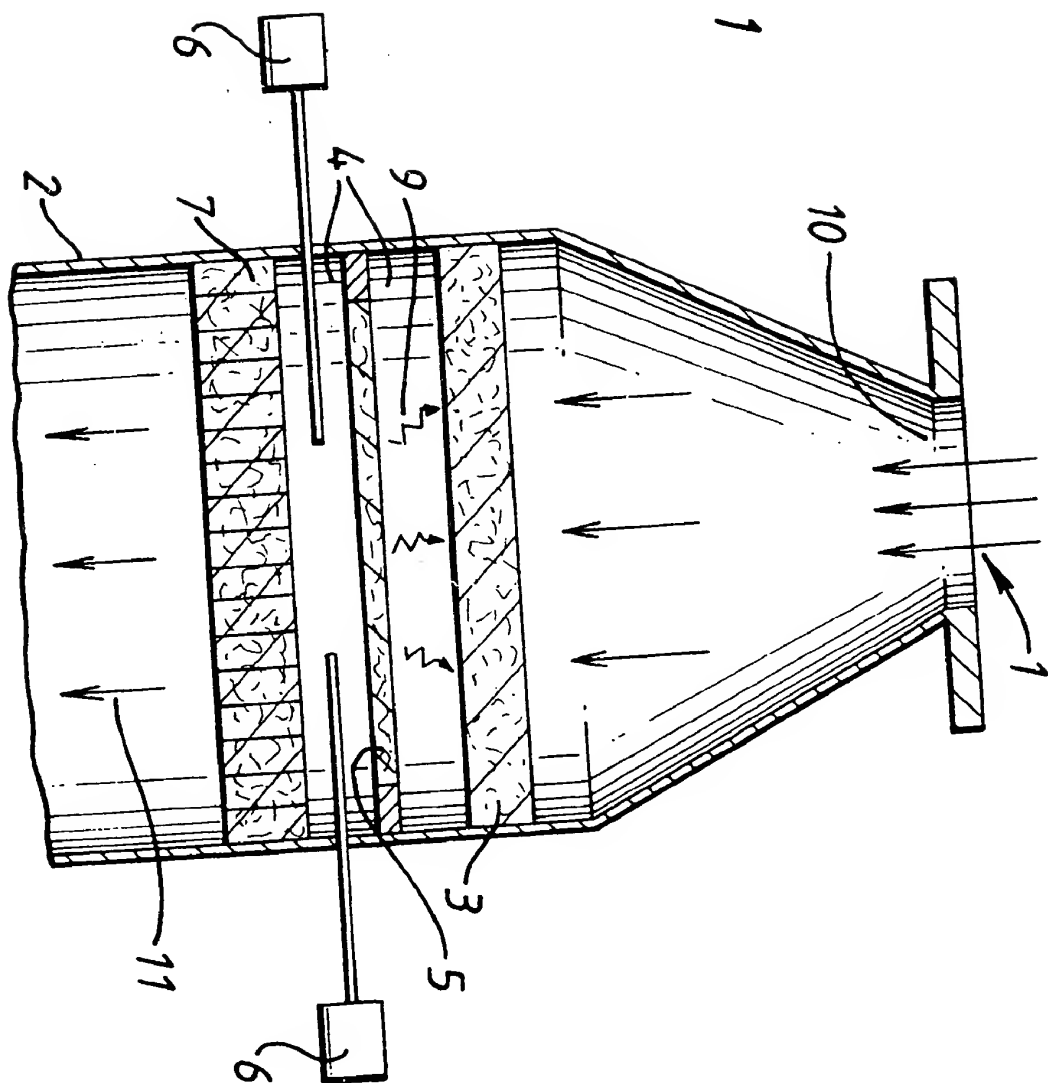
- (A) a reaction zone having a catalyst disposed therein;
- (B) a flow through radiation shield comprising one or more pieces of a flowthrough ceramic material disposed upstream of the reaction zone for
- (i) absorbing at least a portion of radiant energy produced in the reaction zone, and
- (ii) transferring heat formed from absorbing the radiant energy to reactants flowing therethrough into the reaction zone; and
- (C) one or more temperature sensing devices disposed within the reaction zone.

7. The catalyst system of claim 6, wherein the ceramic material is formed from at least one of carbides, nitrides, boronitrides, silicates, and oxides of aluminum, calcium, magnesium, zirconium, yttrium, mixtures thereof and composites thereof.

8. The catalyst system of claim 6, wherein the one or more flowthrough ceramic pieces are one or more ceramic foam tiles having from 5 to 1000 pores per inch.
9. The catalyst system of claim 9, wherein the one or more pieces of ceramic foam tiles are fitted to one another at least on one side.

10. The catalyst system of claim 9, wherein the one or more ceramic foam tiles have a beveled edge on at least one side.

Fig. 1



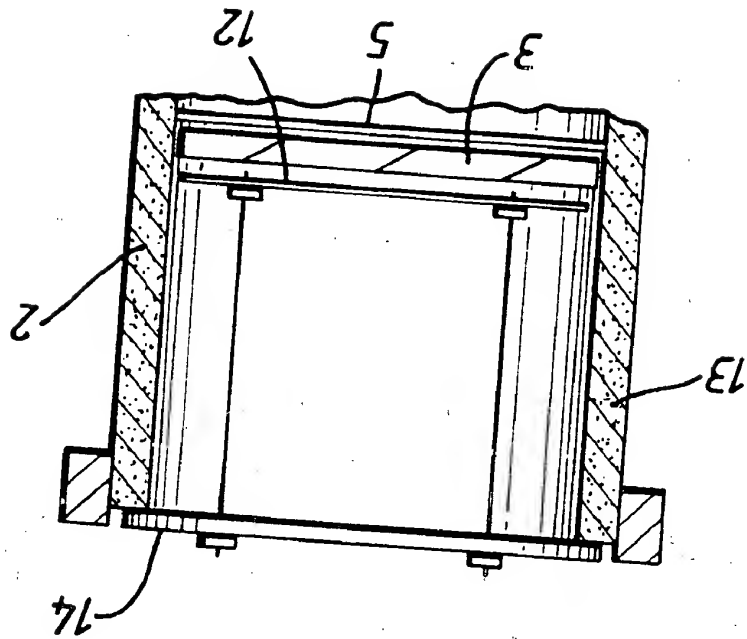
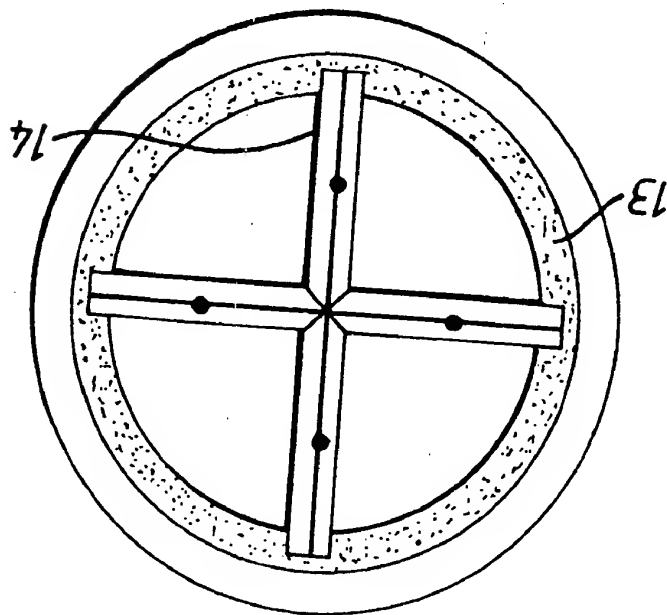


Fig. 2



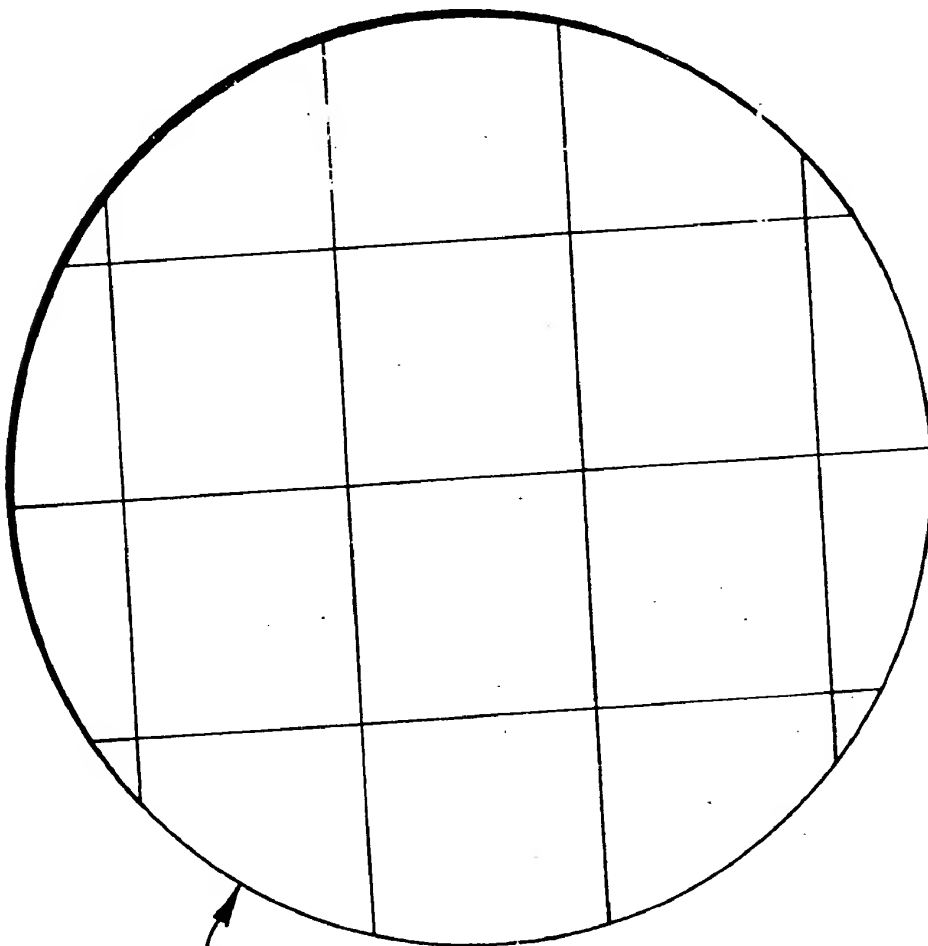
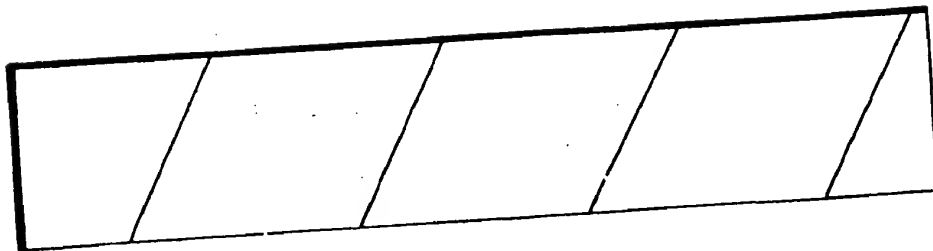


Fig. 3

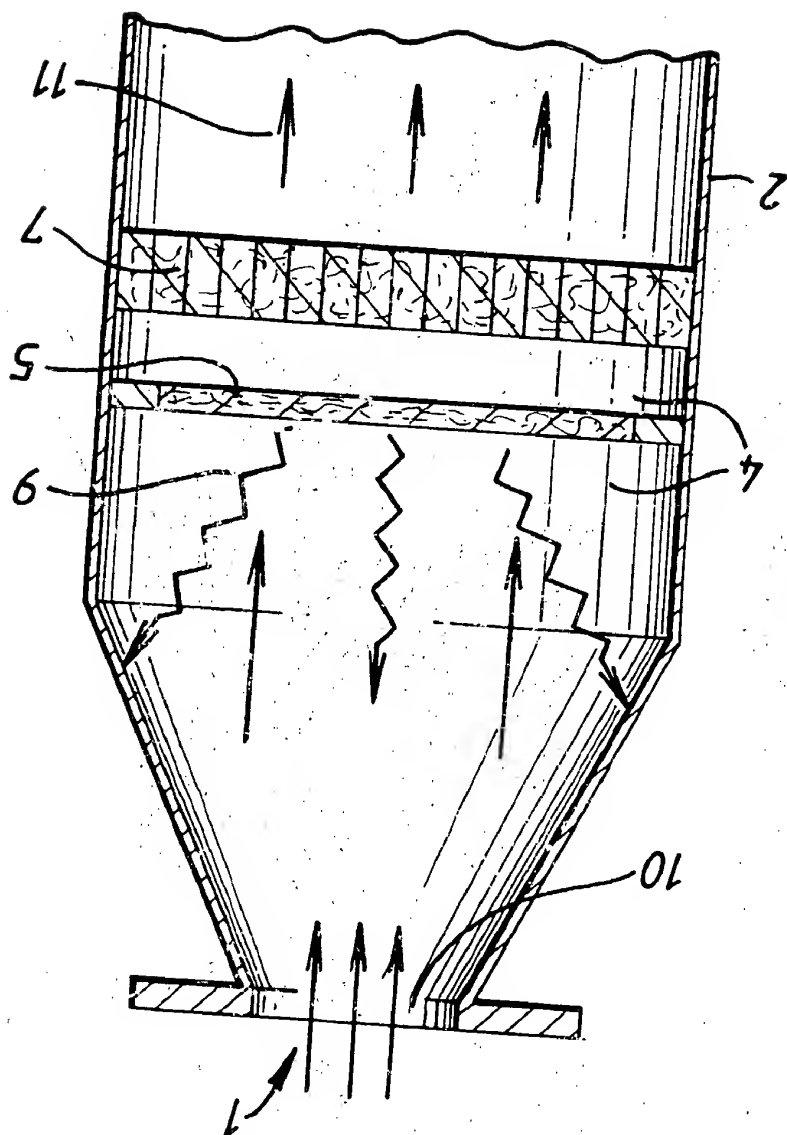
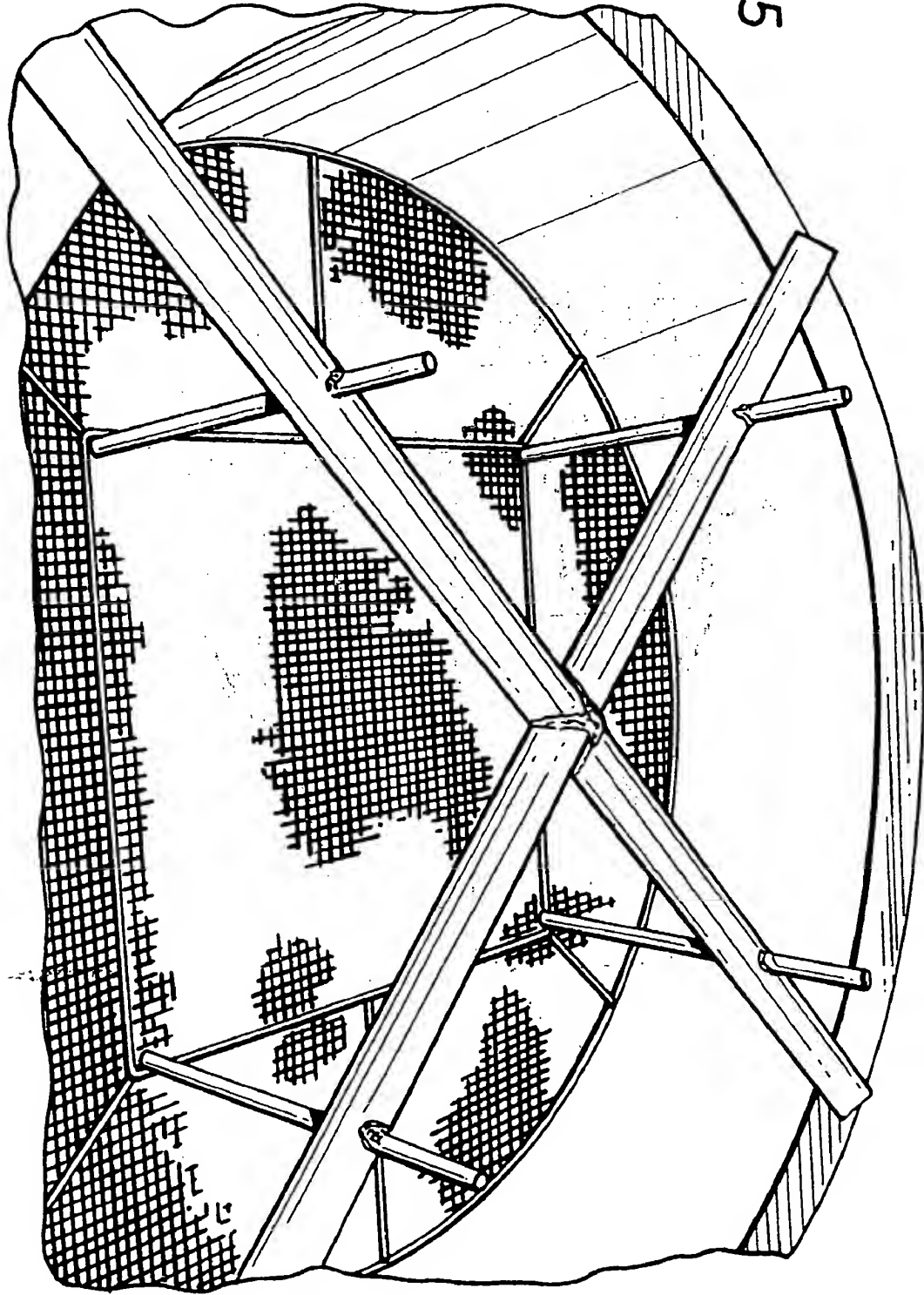


Fig. 4

Fig. 5



EUROPEAN SEARCH REPORT

Office
European Patent



<p>Documents considered to be relevant</p>		<p>Category</p>	
<p>Citation of document with indication, where appropriate, of relevant passages</p>		<p>Relevant to claim</p>	
<p>CLASSIFICATION OF THE APPLICATION (Int.Cl.6)</p>		<p>COIC3/02 B01J12/00</p>	
<p>1.2.6.7, 11</p>		<p>3-5.7-10</p>	
<p>US 3 545 939 A (COX JOHN A JR ET AL) 8 December 1970 (1970-12-08) * column 4, line 46 - column 5, line 5 *</p>		<p>10 November 1965 (1965-11-10) * the whole document *</p>	
<p>GE 1 009 137 A (DU PONT DE NEMOURS) 10 November 1965 (1965-11-10) * the whole document *</p>		<p>US 3 545 939 A (COX JOHN A JR ET AL) 8 December 1970 (1970-12-08) * column 4, line 46 - column 5, line 5 *</p>	
<p>The present search report has been drawn up for all claims</p>			
<p>Place of search</p>		<p>THE HAGUE</p>	
<p>Date of completion of the search</p>		<p>25 August 1999</p>	
<p>Examiner</p>		<p>Zalm, W</p>	
<p>CATEGORY OF CITED DOCUMENTS</p>			
<p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document 8 : member of the same patent family, corresponding document L : document cited for other reasons D : document cited in the application E : earlier patent document, but published on, or after the filing date I : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date</p>			

EP 0 959 042 A1

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO. EP 99 30 3534

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on the European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

25-08-1999

Publication date	Patent family member(s)	Publication date	Patent document cited in search report
02-03-1964	DE 1232934 B FR 1344798 A	08-12-1970	GB 1009137 A
	NONE		US 3545939 A

For more details about this annex: see Official Journal of the European Patent Office, No. 12/82

EP FORM P1459

1. The first part of the report deals with the general situation of the country and the progress of the work during the year. It is a summary of the work done and the results obtained. It is a general statement of the work done and the results obtained.

2. The second part of the report deals with the specific work done during the year. It is a detailed statement of the work done and the results obtained. It is a detailed statement of the work done and the results obtained.

3. The third part of the report deals with the financial statement of the year. It is a statement of the income and expenditure of the year. It is a statement of the income and expenditure of the year.

4. The fourth part of the report deals with the general statement of the work done and the results obtained. It is a general statement of the work done and the results obtained. It is a general statement of the work done and the results obtained.

5. The fifth part of the report deals with the general statement of the work done and the results obtained. It is a general statement of the work done and the results obtained. It is a general statement of the work done and the results obtained.

6. The sixth part of the report deals with the general statement of the work done and the results obtained. It is a general statement of the work done and the results obtained. It is a general statement of the work done and the results obtained.

7. The seventh part of the report deals with the general statement of the work done and the results obtained. It is a general statement of the work done and the results obtained. It is a general statement of the work done and the results obtained.

8. The eighth part of the report deals with the general statement of the work done and the results obtained. It is a general statement of the work done and the results obtained. It is a general statement of the work done and the results obtained.